Development of a Consolidated Multi-Model Ensemble Seasonal Rainfall Forecast System For the U.S.- Affiliated Pacific Islands

A Pacific Region Integrated Data Enterprise (PRIDE) Project

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1. Introduction

The U.S.-Affiliated Pacific Island (USAPI) region (Figure 1) is one of the most vulnerable areas in the world with respect to the impacts of climate-related natural disasters and extreme hydro-meteorological events. Both the Madden-Julian Oscillation (MJO) and the El Niño-Southern Oscillation (ENSO) provide a firm physical basis for seasonal rainfall predictions in this region. Because of decades' effort by the climate modeling community, current General Circulation Models (GCMs) are able to reasonably simulate the large scale atmospheric precipitation patterns with lead times from weeks to seasons (von Storch et al. 1993; Kang et al. 2007), which is potentially quite valuable for the rainfall-dependent communities inhabiting these islands (He and Barnston 1996).

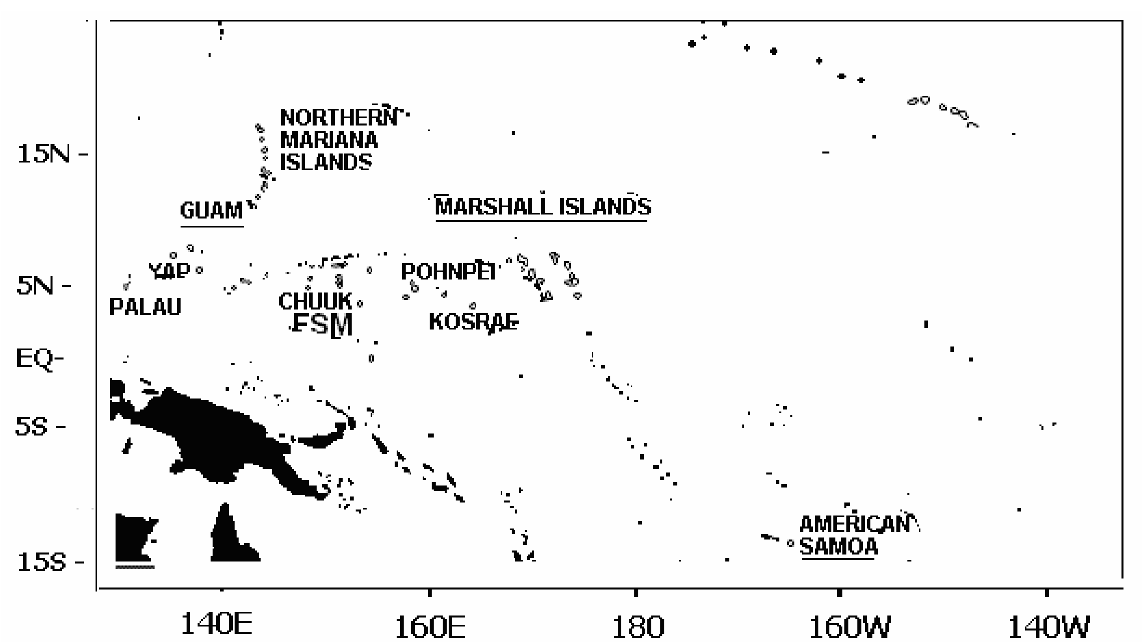

Figure 1 (above): Location of U.S.-Affiliated Pacific Islands.

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Given the presence of steep terrain and relatively small island size, however, the prediction of island rainfall remains a rather large challenge for coarse resolution GCMs. Statistically downscaling (by establishing an empirical statistical relationship between the grid-scale phenomenon and the station precipitation), provides a useful method of resolving this problem (Zorita and von Storch, 1999).

It is generally recognized that using multi-model ensemble (MME) prediction, first introduced by Lorenz in 1963, is superior to using any individual models in climate forecast due to the effective reduction of inherent model errors. The MME relies on good models, thus improvement of models is essential and remains a long-term goal to improving overall forecast skill. In the short term and on a regional scale, an urgent task is to seek optimal MME and downscaling methods to improve operational seasonal rainfall prediction.

2. Objective

The objective of this project is to integrate multiple dynamicalal and statistical seasonal rainfall forecasts using super-ensemble technique to create a useful, objectively consolidated forecast with a lead time of one or two seasons, downscaled to 13 stations within Hawaii and the USAPI.

3. Datasets

Three operational/experimental climate hindcast datasets were used to improve seasonal rainfall forecasts for the Pacific Islands: *i) NOAA/NCEP Global Coupled Atmosphere-Ocean Forecast System (CFS) model; ii) NOAA/NCEP statistical Constructed Analog (CA) model; and iii) University of Hawaii International Pacific Research Center-Hybrid coupled atmosphere-ocean GCM (IPRC_HcGCM).*

The Hybrid coupled atmosphere-ocean GCM (HcGCM) developed at the International Pacific Research Center (IPRC) at the University of Hawaii has been documented in Fu and Wang (2004). In this study, a simple data assimilation scheme (with the sea surface temperature and thermocline depth nudged toward the ocean reanalysis) was implemented to improve the seasonal rainfall predictability. The hindcast from 1982 to 2004 shows useful rainfall anomalies forecast skill with lead times of one to two seasons in the tropical Pacific region.

In addition to the IPRC_HcGCM, 23 years of hindcast datasets (1982-2004) were also collected and analyzed from the NOAA/CPC CA and NOAA/NCEP CFS models. The Pacific ENSO Applications Climate Center provided rainfall observations (1982-2004) from the 13 Pacific Island stations for verification.

4. Methodology

Multi-model super ensemble (multi-variable linear regression) downscaling was employed to generate local seasonal rainfall forecasts for the 13 USAPI stations. Contrary to the previous two-step approach, this technique combines MME and statistical downscaling by directly linking the model forecast large scale seasonal anomalies and the 13 Pacific Island observed rainfall anomalies. A set of season-dependent regression equations were developed and the corresponding hindcast skills were calculated respectively. Because of negligibly small spatial bias, the regression was made with respect to the model forecast value at the grid point nearest the target station for the statistical CA model; whereas the optimal regression equation was established in a “screening” domain near the target station for the two dynamical models. Based on the 23-year hindcast, a pair of grid points (one from CFS and the other from IPRC_HcGCM) were specifically selected within the screening domain to achieve the best overall cross-validated correlation coefficient between the MME-downscaled rainfall and the particular island rainfall observation., The obtained overall cross-validated correlation coefficient was then assumed as the hindcast skill for that specific island.

Once the season-dependent ensemble forecast results were obtained (in standard deviation [SD] units with respect to the climatology and the associated hindcast correlation), the forecast signal was determined, and the correlation coefficient was used as the skill to make seasonal rainfall probability forecast based on the probability forecast method developed by Tippett et al. (2007). (Note that the forecast amplitude should be reduced by multiplying the ratio of the cross-validated correlation coefficient to the non-cross-validated correlation coefficient for operational seasonal rainfall forecast application.)

5. Results

The most recent seasonal rainfall outlook for the 13 Pacific Islands is shown in Table 1 (below), covering five consecutive 3-month seasons: October-December 2007, November-January 2008, December-February 2008, January-March 2008, and February-April 2008. The outlook is provided in tercile (three category) format; thus, probabilities are given in terms of the forecast seasonal precipitation falling into the driest third (below-average tercile), middle third (near-average tercile), and wettest third (above-average tercile) of the years in the climatological period (based on the 30 year period 1971-2000).

Table 1 (below): Forecast Tercile Probabilities for 13 Pacific Island Stations.

Forecast Season	Oct-Nov-Dec 2007			Nov-Dec-Jan 2007-2008			Dec-Jan-Feb 2007-2008			Jan-Feb-Mar 2008			Feb-Mar-Apr 2008		
Tercile	Low	Mid	Up	Low	Mid	Up	Low	Mid	Up	Low	Mid	Up	Low	Mid	Up
Station															
Koror	20	35	45	30	40	30	20	40	40	20	40	40	10	30	60
Yap	20	40	40	10	30	60	10	30	60	15	35	50	15	40	45
Chuuk	40	40	20	15	40	45	20	45	35	55	35	10	65	25	10
Pohnpei	45	35	20	0	10	90	0	15	85	10	25	65	30	40	30
Kwajalein	20	30	50	20	30	50	20	35	45	15	35	50	45	35	20
Majuro	25	35	40	60	30	10	25	35	40	0	10	90	15	30	60
Guam	15	30	55	30	35	35	35	30	35	5	15	80	10	30	60
Saipan	30	30	40	35	30	35	35	30	35	10	20	70	15	25	60
Pago Pago	0	10	90	0	5	95	25	35	40	5	15	80	5	10	85
Lihue	35	30	35	40	30	30	25	35	40	45	30	25	40	35	25
Honolulu	25	35	30	40	35	30	15	30	55	25	35	40	35	35	30
Kahului	35	35	30	25	35	40	45	35	20	55	30	15	60	30	15
Hilo	25	35	40	10	30	60	5	15	80	45	35	20	45	40	15

In the October-December season, there are 8 stations with at least slightly enhanced probability (>38%) of rainfall (falling into the wettest third of the years). Likewise, there are only 2 stations with substantially enhanced rainfall probabilities (>48%), suggesting a close to normal season with only a slight tendency toward the wettest third. The tendency toward above-normal rainfall increases gradually in the following four seasons, consistent with the weak La Niña conditions forecasted to continue through early spring 2008. Both the January-March 2008 and February-April 2008 seasons show 5 stations with substantially enhanced rainfall probabilities falling into the wettest third of the years.

6. Summary and Future Work

MME-downscaling forecast has been developed for the 13 USAPI stations, and is currently being used in conjunction with six other models to create the Pacific ENSO Application Climate Center's Seasonal Rainfall Outlook (issued monthly to NWS-Pacific Region Climate Service Focal Points). Future work includes performing verification of this MME-downscaling forecast using observational data. Forecast results will also be compared with previous subjective forecast results.

7. References

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